Modeling and Forecasting

Kerim Aydin

Ecosystem Science Review
Juneau, Alaska
May 2-6, 2016

# "Ecosystem" models by region

	EBS	GOA	AI	ARCTIC
ROMS/NPZ	*	o		?
Enhanced assessment	*	*	*	
Technical interactions	+			
Food web	+	+	+	o
Multispecies statistical	*	?	o	
FEAST-spatial	*			
IBM	o	o		
Size Spectrum	o			
Qualitative network	?	?		

* Annual or biennial part of assessment, requested or required by Council.
+ Up-to-date for providing issue-specific advice.
O Under active development.
? Proposed.

Bering Sea operational suite

Bering Sea Models

CE-SSM CEATTLE Ecosim Size-Spectru
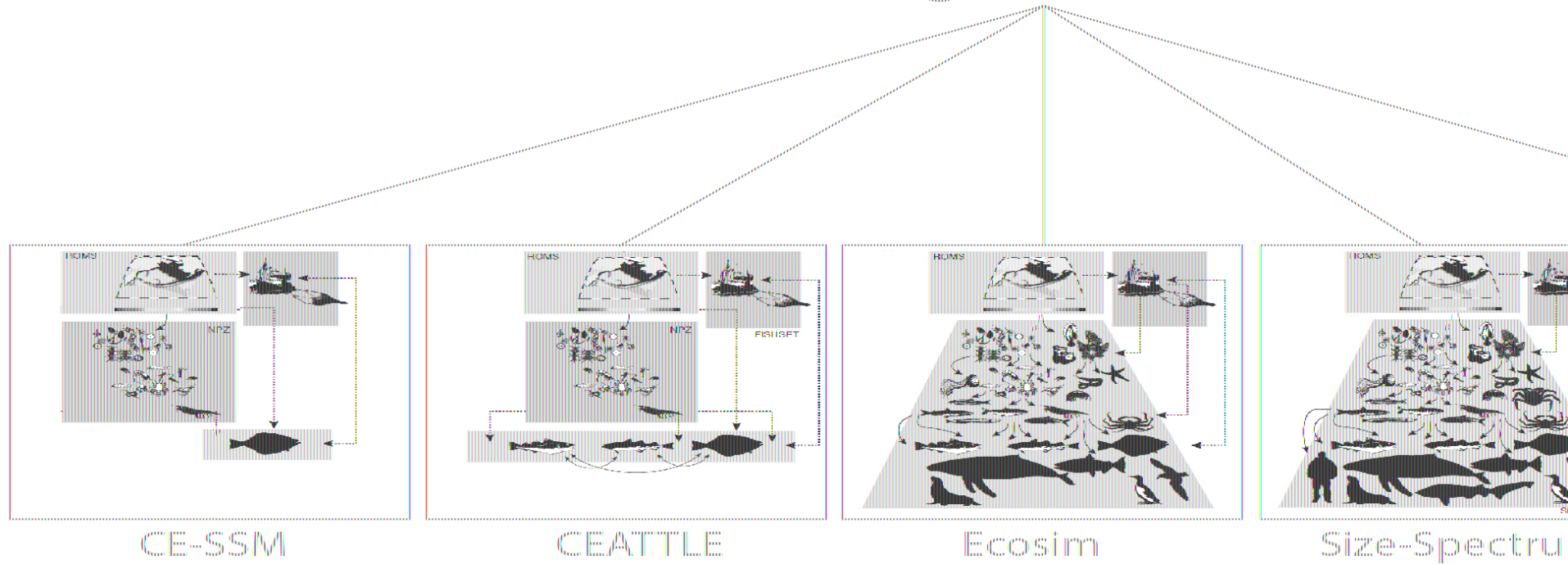
Spatial

Additive Pressures Multiple Interacting (non-linear) Pressures

Non-linear Species Interactions; Non-linear Cumulative Effects

Estimation of Error/ multiple random iterations

Bering ROMS (Regional Oceanographic model)

- Developed with NSF/NPRB (Bering Project)
- Ongoing IEA partnership (AFSC/PMEL)
- Significant advances in ice modeling, ice plankton

- Products
  - 40-year hindcast (1971-2012)
  - Nowcasts (annual)
  - 9-month forecast (annual)
  - Forecasts to 2100 with IPCC outputs
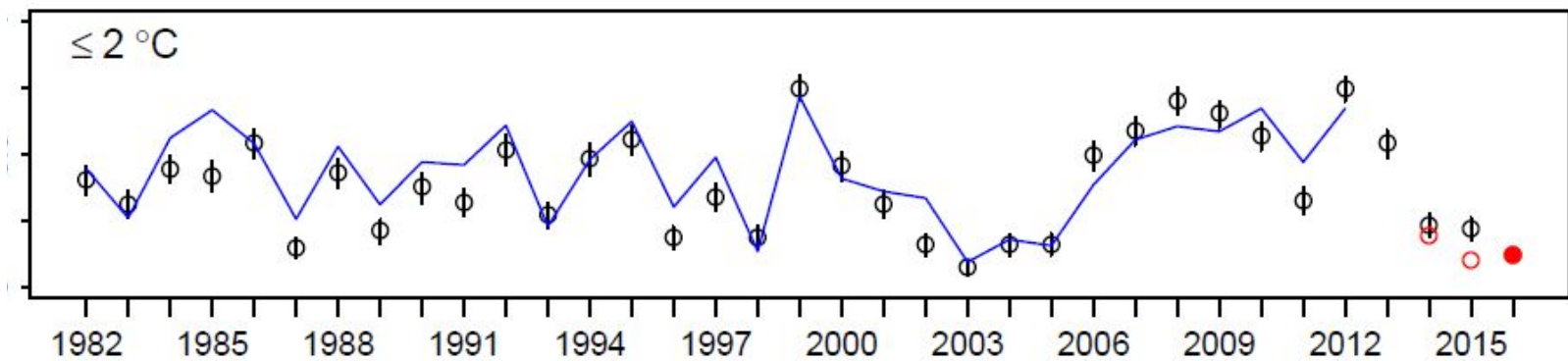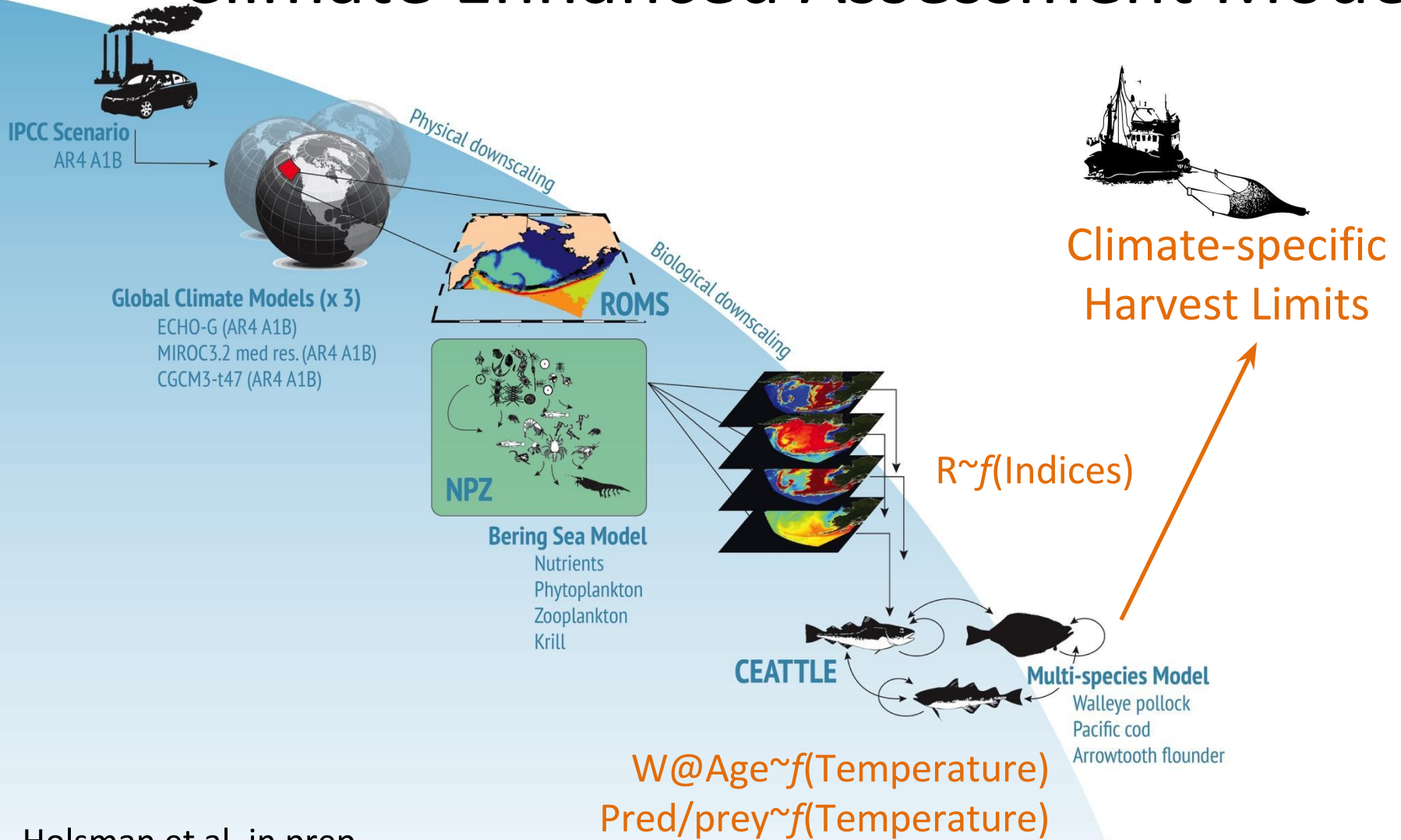 - Rapid Climate Assessment

2004 JUN

2008 JUN

Ice cover
& algae

cold
pool

Ice cover
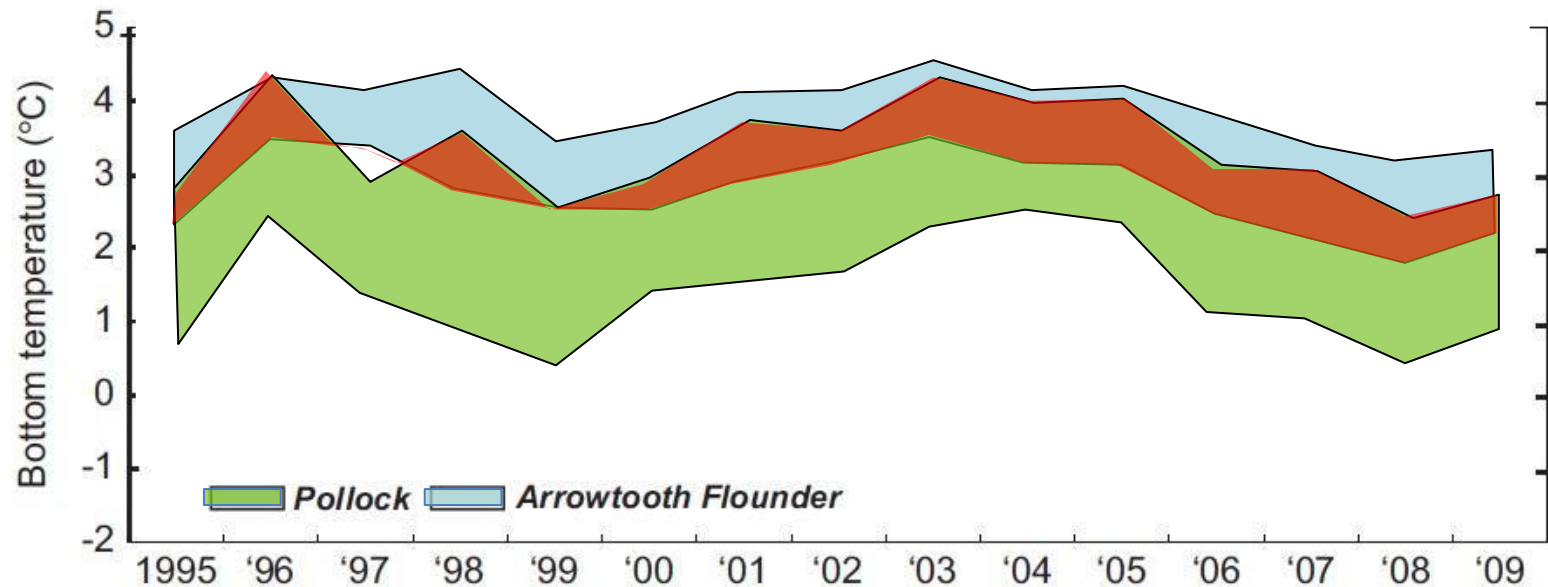& algae
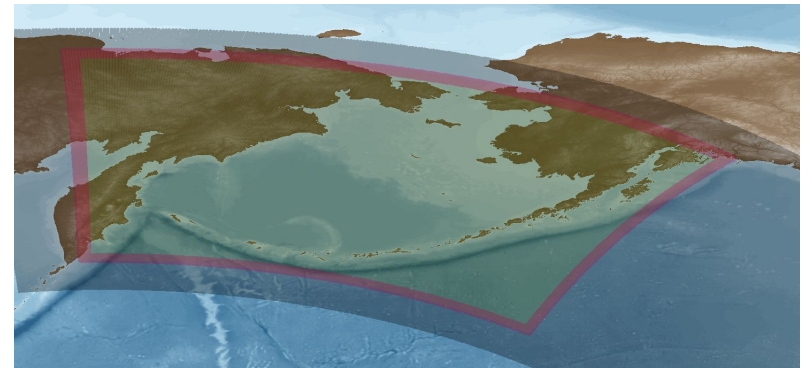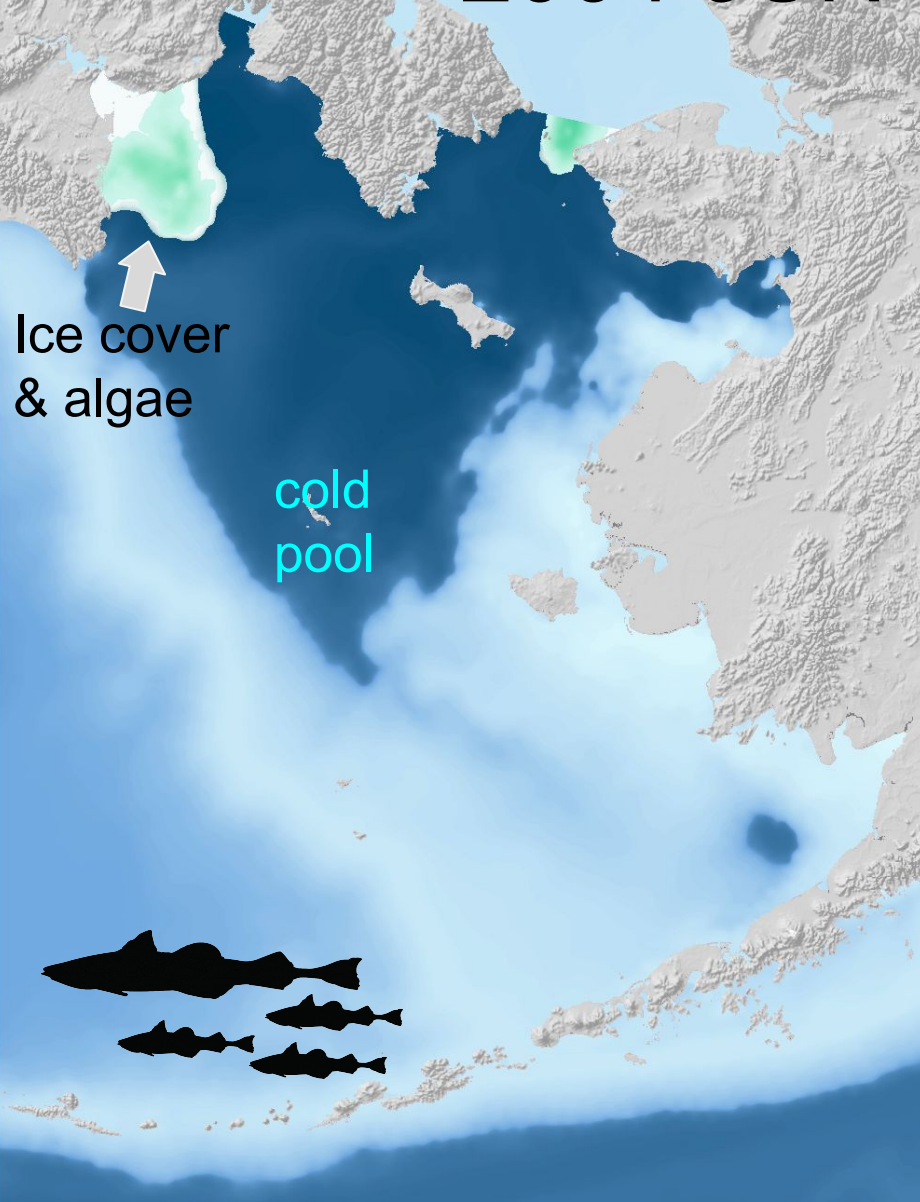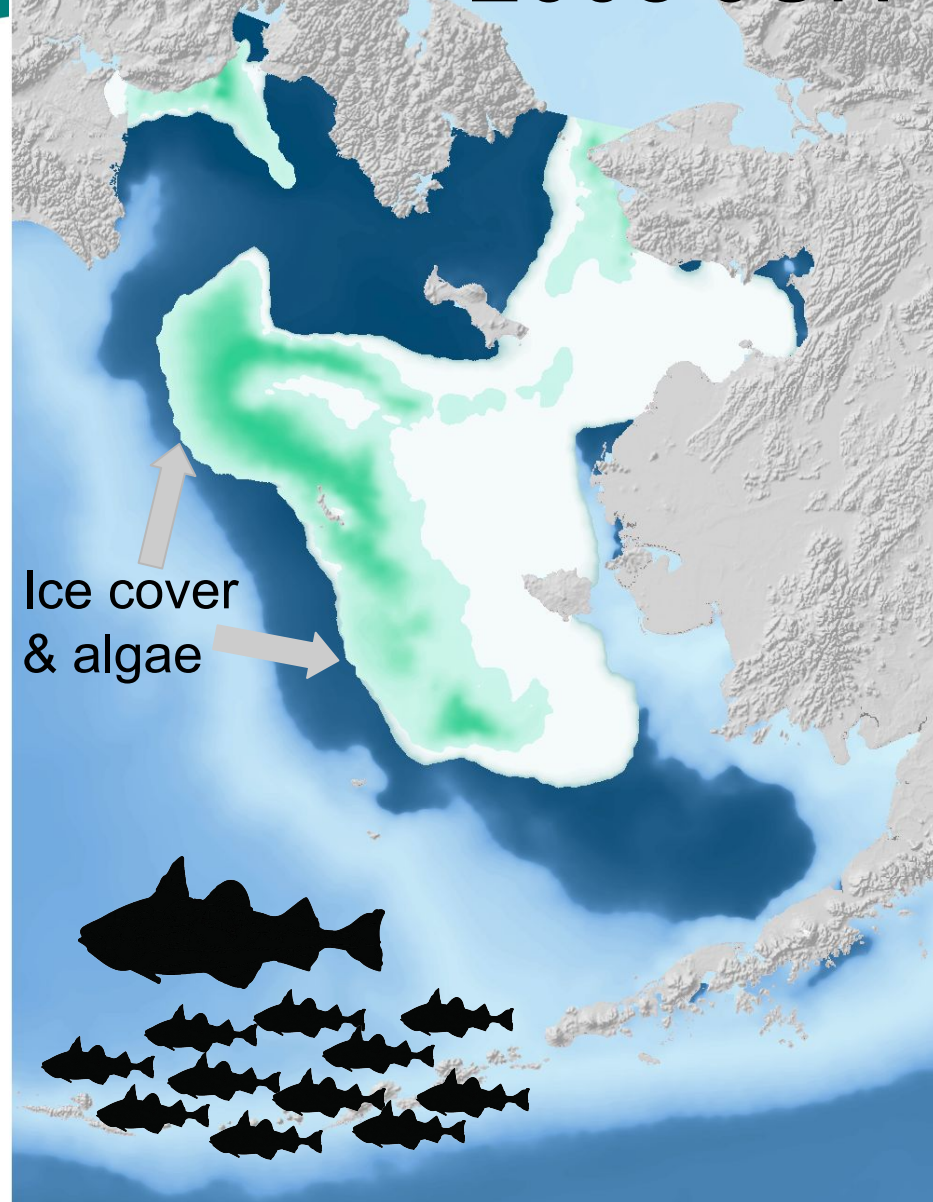
9-month forecast – cold pool

- Included in annual ecosystem chapter (November prediction for following summer)
- Strong traction/interest in fishing community
- Forecast led to increased oceanographic field presence in 2015 (unprecedented warmth forecast)
- Review: not all metrics well-predicted; e.g. SST shows biases.

Climate Enhanced Assessment Models

IPCC Scenario
AR4 A1B

Physical downscaling

Global Climate Models (x 3)
ECHO-G (AR4 A1B)
MIROC3.2 med res. (AR4 A1B)
CGCM3-t47 (AR4 A1B)

ROMS

Biological downscaling

NPZ

Bering Sea Model
Nutrients
Phytoplankton
Zooplankton
Krill

CEATTLE

Multi-species Model
Walleye pollock
Pacific cod
Arrowtooth flounder

Climate-specific Harvest Limits

R~f(Indices)

W@Age~f(Temperature)
Pred/prey~f(Temperature)
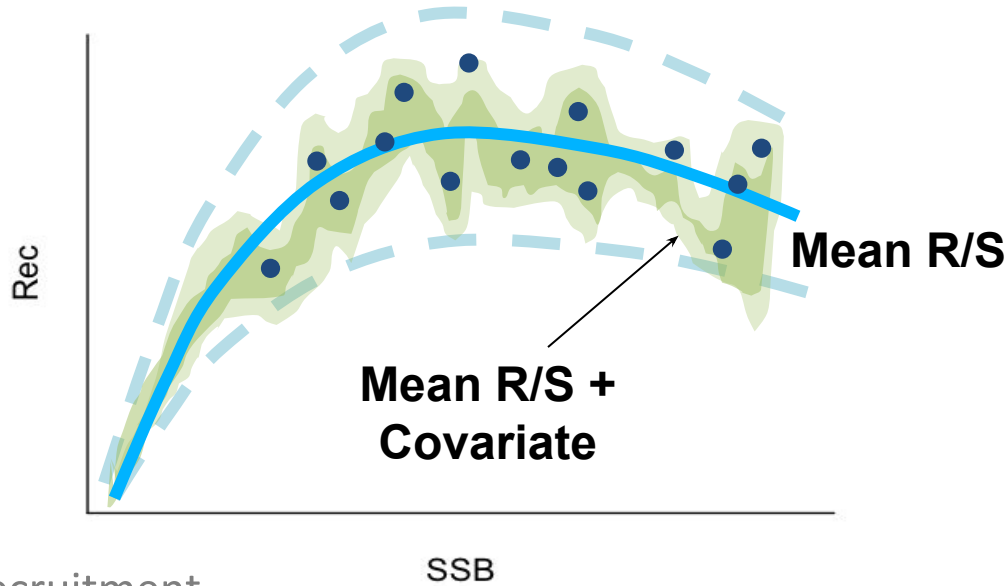
Holsman et al. in prep

Pred-prey overlap based on thermal envelopes

Stabeno et al. (2013) A comparison of the physics of the northern and southern shelves of the eastern Bering Sea and some implications for the ecosystem. Deep-Sea Res II 65-7014-30.
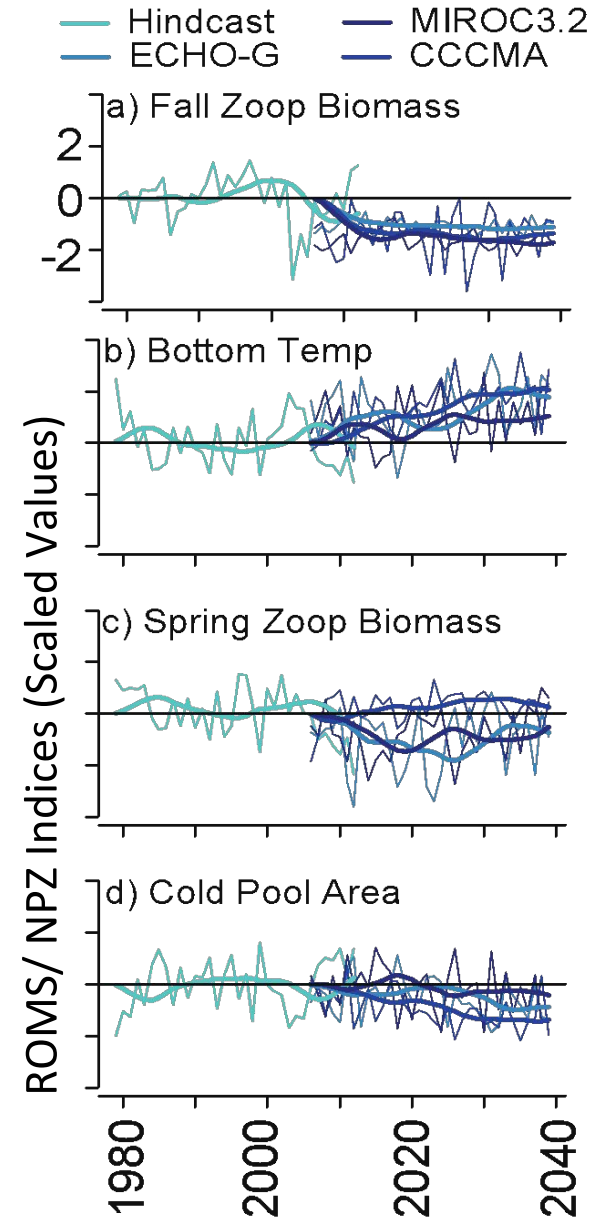
CEATTLE Recruitment – ROMS forced forecasts

Mean R/S

Mean R/S + Covariate

recruitment

$$log(R_t) = log(\alpha \cdot B_{t-1}) - \beta_1 \cdot B_{t-1} + \sum \beta_k \cdot X_{k,t} + \varepsilon,$$

productivity

carrying capacity

environmental effects on carrying capacity

Hindcast   MIROC3.2
ECHO-G   CCCMA

a) Fall Zoop Biomass

b) Bottom Temp

c) Spring Zoop Biomass

d) Cold Pool Area

ROMS/ NPZ Indices (Scaled Values)

1980   2000   2020   2040

FEAST – 10km² Bering Grid trophic structure and population dynamics
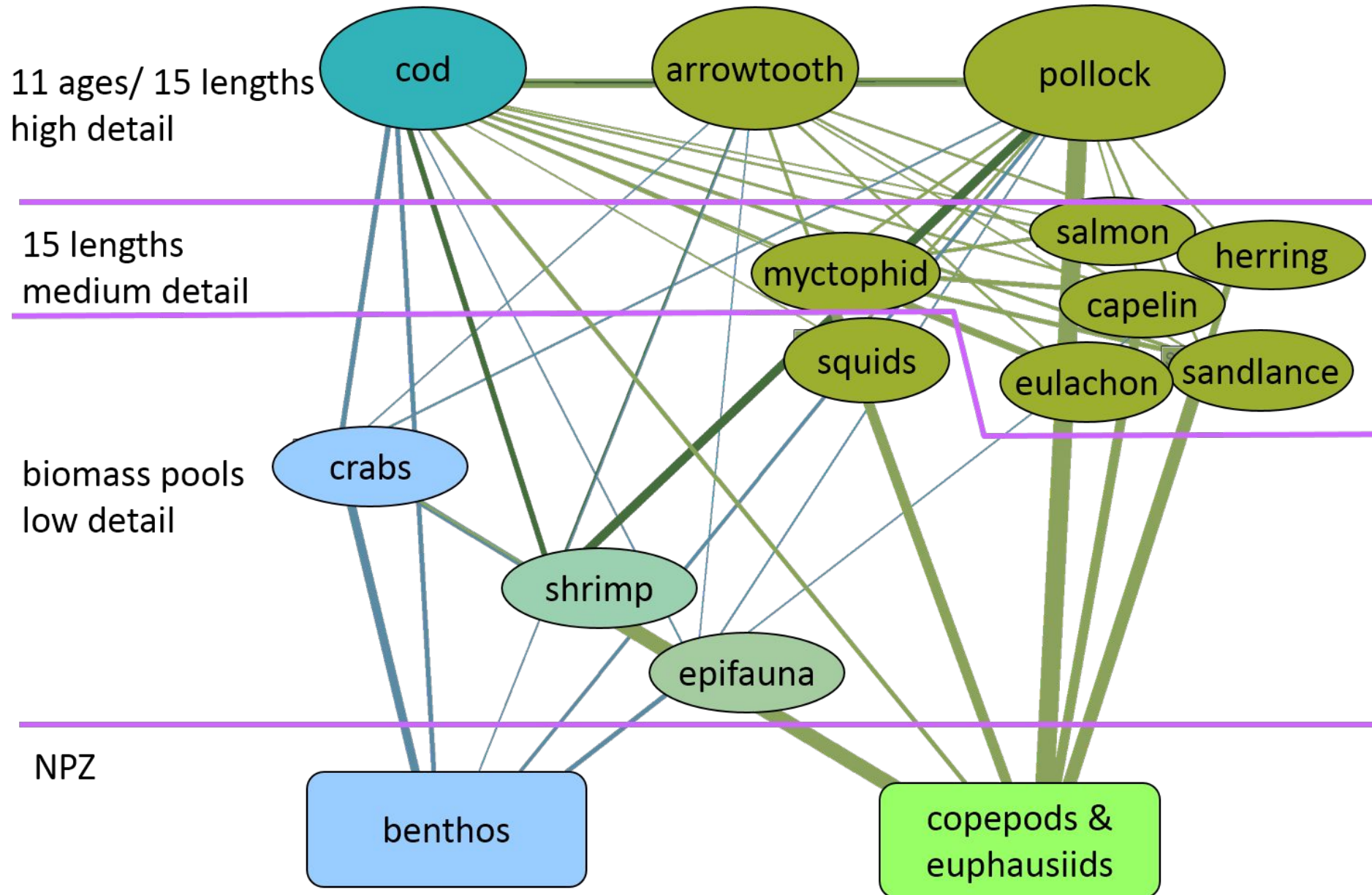
FEAST – Forage Euphausiid Abundance in Space and Time

Forage-fish centered, driven by diet interactions

Size/species prey preference

Age, length, species

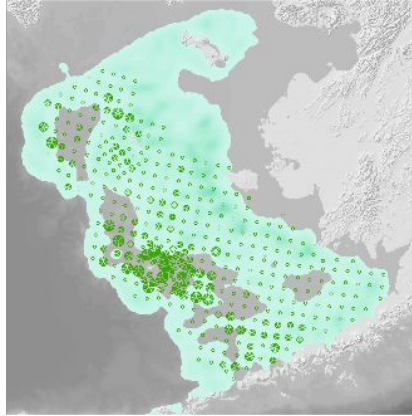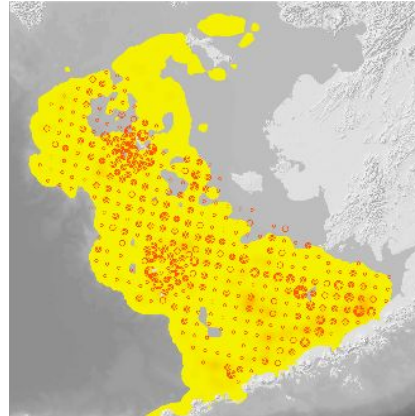Percent weight in pollock diet of copepods, euphausiids and pollock
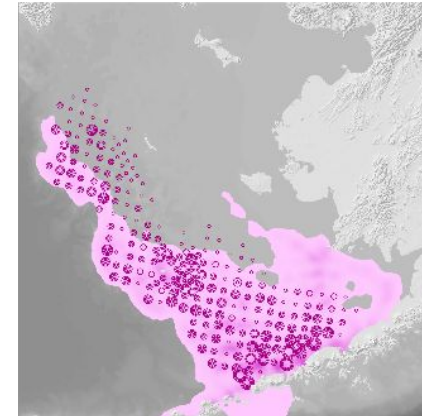
Summer adult distribution – FEAST vs data

Pollock   Cod   Arrowtooth

2004

2008

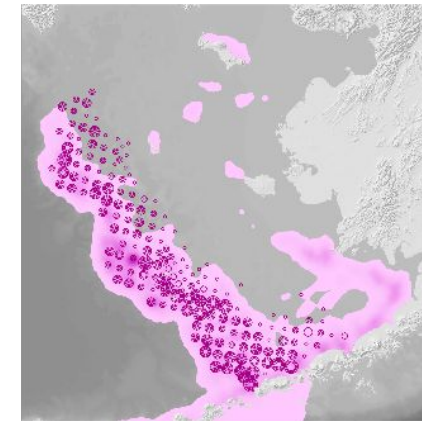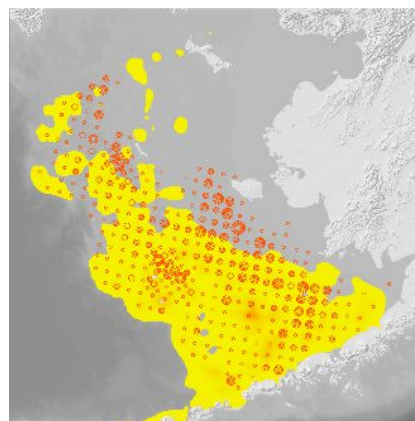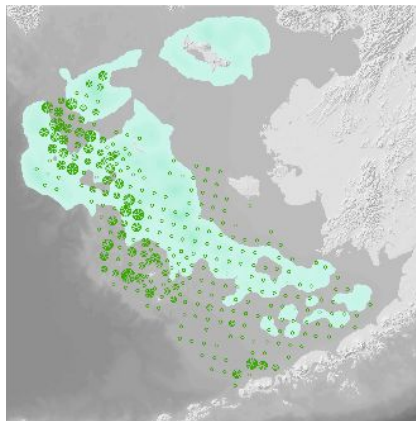Circles are bottom-trawl data; shading is FEAST modeled distribution

FEAST uses

- Primarily for forage fish/zooplankton interactions with climate

- Not "whole ecosystem" – missing benthos (flatfish, crabs)

- Includes fleets, future fleet predictive dynamics

- Predicts conditions for predators
  - Specific management uses: Cod and ATF explicitly; fur seals, birds, Chinook salmon implicitly

Data types and availability

	RAW	Magnitude estimates	Rates	Process	ad hoc
PMEL	○		○	○	◎
BASIS	○			○	◎
ECOFOCI	○			○	
MACE	○	○			
RACE	●	●	●	●	◉
FOODLAB	●	●		●	◉
NMML	○	○	○	○	
OBSERVERS	●				◉
	●		●		◉
CAS	○	○			◎
EXTERNAL					

○ Database nonpublic   ● Database public   ◎ Modeler developed from nonpublic   ◉ Modeler developed from public

Data flow to models

PMEL

BASIS

ECOFOCI

MACE

RACE

FOODLAB

NMML

OBSERVERS

CAS

External

FEAST

ECOPATH

CEATTLE

ECOSYSTEM INDICATORS
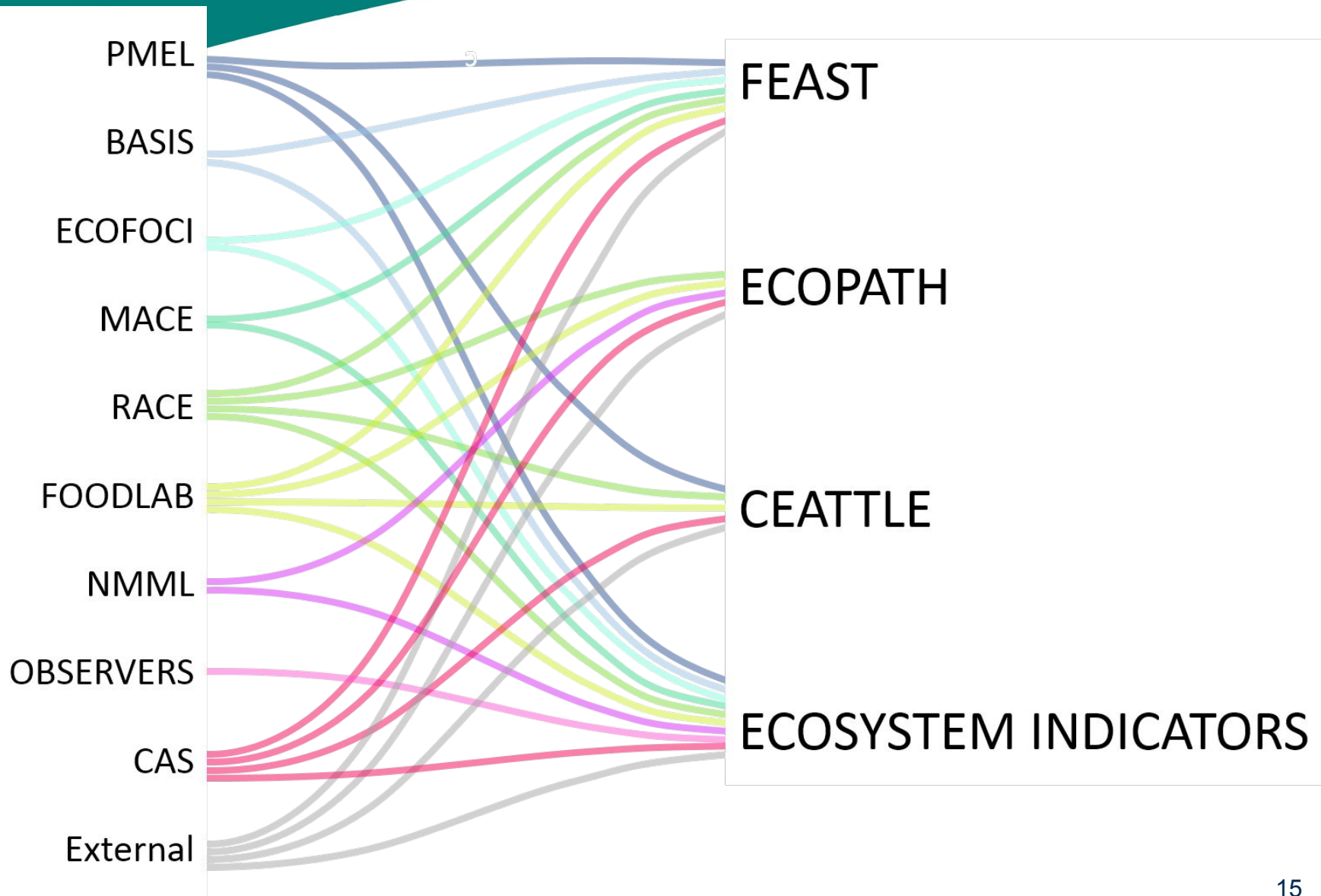
Food web modeling – Ecopath/Ecosim

- All four regions
- Multiple reviewed uses in ecosystem assessment (2005-present)
- Annual assessment use: guild-level analysis
- **Cumulative/ecosystem level indicators**
- R-based fitting tools/development

Technical Interactions Model

(Ono et al.)

- Single-species stock assessment models linked through interacting gears (no interspecies interactions).

- Model and predict fisheries given wide range of current constraints.

- "Human behavior realistic" cumulative catch and constraints.

1. $\sum_{k=1}^{n_{metier}} d_{k,t} C_{j,k,t} \leq TAC_{j,t}$ *"Target species quota constraints"*
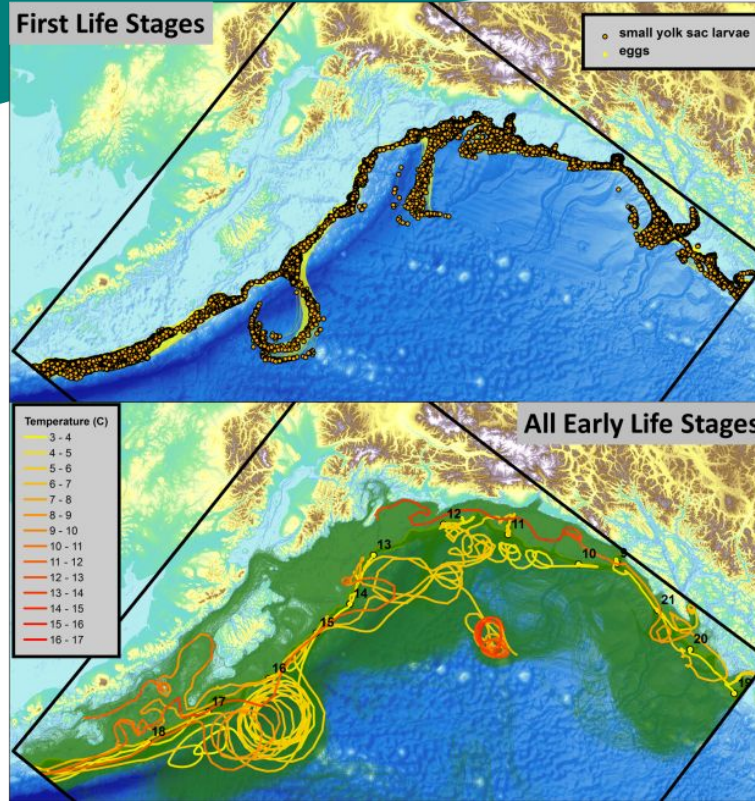
2. $\sum_{k}^{n_{metier}} d_{k,t} C_{bycatch,k,t} \leq$ Bycatch limit   *"Bycatch limit = 4575 (halibut limit)"*

3. $\sum_{k=1}^{n_{metier}} \sum_{j=1}^{n_{species}} d_{k,t} C_{j,k,t} \leq$ Hard cap on yield   *"The hard cap" = $1.7e^6$ t*

4. $\lambda_1 d_{k,t=1} \leq d_{k,t} \leq \lambda_2 d_{k,t=1}$ *"Métier concentration factor: contraction (λ_1)/expansion (λ_2)"*

Gulf of Alaska Modeling

- GOA-IERP developed ROMS model, IBM models for recruitment.
- Freshwater input and other dynamics not strongly captured by current atmospheric forcing, still in "research" mode.
- GOA-IEA pre-modeling steps: Conceptual Model building (stakeholder/scientists)

TOR 6: Inclusion

- Annual indices part of ecosystem chapter
  — Guild biomass and exploitation, natural mortality estimates
- Inclusion of 9-month forecast indices based on predictive power in hindcasts
- 5-year strategic re-assessment of climate forecasts part of FEP Action Module
- ROMS/NPZ projections will form the basis of the Climate Vulnerability Assessment
- Climate Science Strategy will include outputs from ACLIM model suite

TOR 7: peer review

- ROMS physical results reviewed for indicator provision
- Starting 2016, CEATTLE to be reviewed as "alternate" model in EBS pollock stock assessment
- Ecopath models underwent CIE review for management purposes
- Evaluating robustness of ecosystem indicators under climate change (FATE project)
- Evaluation of thermal envelopes of commercial groundfish under climate change

TOR 8: communication

- MSEs conducted/in progress with stakeholder input
- Outputs (hindcast, long-term forecast) available on AOOS, other web portals
- ACLIM includes webinars and iterative discussion with councils

Strengths, Challenges, Solutions

S: History of frequent and consistent **communication** of a variety of products with the Council; Models and Ecosystem Consideration reports are **bridges** among programs.

C: Council needs consistently delivered products but also flexibility for evolution of content; Updates have been opportunistic and project based; Lack of a structured portfolio of AFSC, regional, and national ecosystem activities to enhance efficient, iterative, communication between AFSC, councils, and stakeholders

S: Develop ecosystem portfolio (e.g. including stakeholder-driven conceptual models), have AFSC and Council prioritize and define.

PORTFOLIO GAP EXAMPLE: There is no AFSC "Research Alliance" for adult fish on par with RPA for recruits - need to coordinate/prioritize field research on adult life-history, growth, feeding movement, local depletion, fisher & protected species interactions.

S: DATA IN: sharing culture, strong use of accessible, known databases, **RESULTS OUT:** Large variety of products (models, reports, eco-indicators) for 4 LMEs.

C: Internal databases lack universal access; models and indicators need regular updates; poor data awareness, many model output requests internally and externally.

S: Establish open access databases across divisions, improve both internal and external scripts library and web-tools for data access and exploration, make consistent data/indicator provision part of performance plans.

S: Cutting-edge **high-performance computing** work AFSC/PMEL/UW.

C: HPC & large data handling (transfer, storage) resources strained; DOC IT policies hinder collaboration.

S: Update infrastructure with expectation of "big computing"; explore NOAA HPC, universities, cloud.

S: Multimodel ensemble suite suitable for management stays up-to-date with unique data source (food habits).

C: For management needs, suite needs to be kept updated consistently but uses soft/unstable funding.

S: Increase **stable funding sources/FTEs** for both ecosystem modeling and food habits program(s) to establish operational status on par with stock assessments.